1905MNRAS..65..513F

Spectroscopic Observations of the Recent Great Sun-spot and Associated Prominences. By A. Fowler.

Introductory.

The great sun-spot which was so conspicuous during the last three days of January and the early part of February presented several features of interest when examined with the spectroscope, and it may be useful to give an account of the phenomena observed. Observations of the spectrum were made on January 31, February 1, 2, and 3, and after the return of the spot on February 25, 28, March 3 and 6. The prominences overlying the spot as it passed over the western limb on February 11 were also observed and the spectrum recorded in considerable detail.

All the observations were made with an Evershed solar spectroscope attached to a 6-inch refractor.

Reversals of Lines.

During the first passage of the spot across the disc the C and F lines of hydrogen were brightly reversed, but on its return the reversals were less pronounced and could not be seen at all on March 6. The D_3 line of helium was a prominent feature for a short time on February 2, and was also noted on February 25. Reversals of the sodium lines D_1 and D_2 were very conspicuous during the earlier stages, but were not seen after the return of the spot. The magnesium lines b_1, b_2, and b_4 and the iron line b_3 were observed to be reversed on January 31, and again, together with many other lines, on February 2. Details of the observations are as follows:

January 31 (9.50 A.M.–2.30 P.M.).—C and F were brilliantly reversed in numerous places over a large area, and especially over the greater part of the largest umbra. D_3 was suspected as a bright line. D_1 and D_2 were brightly reversed over the two largest umbræ, and the four *b* lines were seen bright on the inner edge of the principal umbra, where C and F were brightest. The displacements of the lines were very slight.

February 1 (11–11.20 A.M.).—C and F were reversed as on the previous day, but the displacement of the (dark) lines were more marked; the greatest displacement was about 2 tenth metres. D_3 was not observed, but D_1 and D_2 were reversed as on January 31.

February 2 (9.45–12).—From 9.45 to 10 A.M. there was an eruption over the spot, during which the C line in a region preceding the principal umbra was expanded into a cloudy form extending about 5 tenth metres towards the red; over the umbra the line was also brilliantly reversed, but occupied its normal position. D_3 was also very conspicuous, and, so far as

1905MNRAS..65..513F

could be determined, its appearance was similar to that of the C line, except that it could not be traced quite so far from the normal position : it changed from bright to dark as the position of the spot upon the slit was varied.

During this eruption, at the place where C, F, and D_3 were most brilliant, all the Fraunhofer lines seemed to be either obliterated or reversed. There was only time to note the wave-lengths of a few of the bright lines but among them were certainly the helium line 6678·3, the D lines of sodium, the enhanced line of iron 5316·79 (1474 K), the iron line 5269·7 (E_2), the four *b* lines, and the enhanced iron lines 5018·6 and 4924·1 ; they were, in fact, among those most frequently observed in the spectra of metallic prominences on the Sun's limb. These bright lines did not appear to be in the least displaced from their normal positions.

At 10 A.M. the metallic lines had disappeared and the bright D_3 line over the umbra was greatly enfeebled, though it remained visible for some time as a faint dark line in the region preceding the umbra. At 11.10 A.M. D_3 was again seen as a bright line over one of the smaller umbræ at a place where the D lines were also reversed.

February 3 (9.50–12.30).—Though reversed in many places over the spot area, C and F were nowhere very bright, and D_3 was not detected. D_1 and D_2 were reversed over the largest umbra, where C and F were brightest.

February 25 (10.50–12.40).—After return of spot. C and F were still reversed over the largest umbra, and D_3 was also seen as a feeble bright line in the same region. D_1 and D_2 were much widened, but reversal was not certainly detected. Although the spot appeared to be well within the limb, the adjacent chromosphere was considerably disturbed, and several of the brighter chromospheric lines, including 5535·0, 5363·0, 5284·2, 5276·2, and 5197·8, were noted.

February 28 (9.50–12.30).—C and F were "knotted" and somewhat feebly reversed in several places, and, as before, they were brightest on the preceding edge of the largest umbra. D_3 was not detected, and no reversals of any metallic lines were observed.

March 3 (10–12).—The appearances were very similar to those of February 28.

March 6 (12.30–1).—The spot was now greatly reduced in size, and nothing abnormal about C, F, or D_3 was observed.

The phenomena which have been described seem to be sufficiently explained by the presence over the spot of prominences of varying activity, and it will be gathered that the greatest action was exhibited near the preceding edge of the largest umbra. Rapidly changing prominences were in fact observed on February 11, when the spot was on the Sun's limb.

As indicating that the appearance of D_3 is not restricted to very large spots, it may be mentioned that this line was very

1905MNRAS..65..513F

prominent in the peculiar group of small spots seen in the eastern hemisphere on February 22; it then appeared as a broken and contorted dark line resembling C and F.

The Widened Lines.

General examinations of the spectrum of the largest umbra indicated that the "most widened" or most strengthened lines were not notably different from those recently observed in other spots. In other words, the majority of the affected lines could be traced to vanadium, titanium, chromium, scandium, sodium, calcium, and iron.

Selected parts of the spectrum were examined very minutely, the intensities of the lines being estimated by comparison with the Fraunhofer lines outside the spot spectrum. The result of these observations is to indicate that the spectrum, apart from the superficial effects already described, was sensibly constant from day to day, and was not materially different from that of another spot observed on the same plan on January 18. Thus, out of forty-six lines recorded in the great spot on January 31 in the region 5170–5239·2 forty-four appeared in the record for the corresponding part of the spectrum on February 1, and thirty-five of the forty lines recorded on February 28 in the region 5198·9–5239·2 appeared also in the previous lists. In the spot of January 18 forty affected lines were noted in the region 5188–5266, and thirty-seven of these occur among the lines recorded in the same part of the spectrum of the great spot. Considering the difficulty attending the observations, the differences are probably not significant.

The Spot Bands and General Absorption.

The bands of the sun-spot spectrum in the red, near 6381 and 6390, as well as those in the region more refrangible than *b*, were very strongly marked in the larger umbræ, and were always seen when looked for.

In the earlier observations the resolution of the general band of absorption, as described by Young[*] and Dunér,[†] was seen very clearly, although I had previously believed the dispersion at my disposal inadequate to show it. Probably the large dimensions of the umbra rendered the structure more visible. The resolution was best displayed by the bright gaps which occur here and there among the closely crowded dark components, and, as already noted by the observers named, these bright gaps are of the same brightness as the undimmed photospheric spectrum outside the spot. The general appearance of the band was very similar to that of a complex banded spectrum, such as that of sulphur, in which the maxima or "heads" are not very pronounced.

---

[*] *American Jour. Sci.* 3rd series, vol. xxvi. p. 333 (1883).

[†] *Recherches sur la Rotation du Soleil* (Upsala, 1891).

1905MNRAS..65..513F

Under favourable conditions Young and Dunér were able to trace the dark components of the spot-band structure in the spectrum of the disc outside the spot, but this was not clearly seen in my observations; the same effect, however, is to some extent indicated by the fact that in some cases, the bright gaps occupy the spaces between nebulous lines of low intensity tabulated by Rowland. Three examples are as follows:—

Bright Gaps in Spot Band.	Solar Lines (Rowland).		
5160·8	5160·42	00	N
	5160·55	0000	
	5161·01	0000	N
5201·6	5201·46	0000	N
	5201·77	0000	N
5259·4	5259·26	0000	N
	5259·66	000	N

It is accordingly not improbable that the absorbing vapour which is chiefly responsible for the darkness of a spot is thinly distributed over the general surface of the Sun, and may account for some of the very numerous faint lines of the Fraunhofer spectrum. At all events the appearance of the spot-band is in complete accordance with the view that the darkness of a spot is due to absorption and not to defective radiation from the stratum beneath the spot. Further, as pointed out by Young, the absorption must be produced by matter in the gaseous form, and not by solid or liquid particles.

Spectrum of Chromosphere and Prominences overlying Spot on Western Limb.

Magnificent prominences of rapidly changing form, varying in height from one to two minutes of arc, were observed on the morning of February 11, when the spot was passing over the western limb. The appearance mostly resembled one or more jets from a hose-pipe, and it was noted that in each case the streams were directed towards the equator.

The chromosphere was greatly disturbed to a considerable height, as indicated by the numerous long or "high-level" lines seen with a tangential slit, while still more intense action was evidenced by the appearance of many short metallic lines in the spectrum of the stump of one of the prominences.

The observing conditions were by no means good, but the positions of sixty-seven of the bright lines were ascertained by reference to Rowland's map. Seeing that so few observations of these bright lines, other than those of Young, have been published, it may be that details of the observations will be of value. In the following table the wave-lengths are indicated in the first column; in the second column the approximate intensities are

1905MNRAS..65..513F

shown by the numbers, while "l" and "s" respectively indicate whether the lines were long or short; the third column shows the origins which seem to be most probable, taking account of intensities of the lines and recognising that enhanced lines are specially developed in the chromospheric spectrum; columns 4 and 5 indicate the frequency and brightness of the corresponding lines given by Young.* Following Sir Norman Lockyer, enhanced lines are indicated by the prefix "p," so that "p Fe" reads as "proto-iron," &c. These special lines have been chiefly identified by reference to the table of chromospheric lines given by Sir Norman Lockyer in the report on the eclipse of 1898 January 22.†

Wave-length.	Intensity and Character.	Probable Origin.	Young. Fre-quency.	Young. Bright-ness.	Remarks.
4861·53	100 l	H	100	80	F. Expanded on both sides.
4922·10	15 l	He	30	8	No attempt could be made to record all the bright lines in this region.
4924·11	25 l	p Fe	40	10	
5015·73	20 l	He	30	10	
5018·63	25 l	p Fe	30	15	
5167·50	20 l	Mg	20	10	b_4
5169·22	40 l	p Fe	40	25	b_3
5172·86	30 l	Mg	50	30	b_2
5183·79	40 l	Mg	50	35	b_1
5188·86	15 s	p Ti	10	5	Not seen separately
5189·02		Ca			
5197·8	25 l	...	10	10	
5200·4	10 s	...	2	4	Possibly Cr.
5202·52	10 s	Fe	4	3	
5204·68	15 s	Cr	4	5	Not seen separately.
5204·77		Fe			
5206·22	15 s	Cr, Ti	4	5	
5208·60	15 s	Cr	4	5	Both components were reversed.
5208·78	15 s	Fe			
5227·04	20 s	Fe, Cr	3	3	Both components were reversed.
5227·36	20 s	Fe			
5239·47	25 l	...	10	10	

---

* Scheiner's *Astronomical Spectroscopy*, pp. 423–426, and p. 184.

† *Phil. Trans.* vol. 197A, p. 151.

1905MNRAS..65..513F

Wave-length.	Intensity and Character.	Probable Origin.	Young.		Remarks.
			Frequency.	Brightness.	
5265·0	15 l	...	3	3	
5269·72	30 s	Fe	10	2	E_2.
5270·44 5270·56	25 s	Ca Fe	5	2	E_1. Not seen separately.
5276·17 5276·24	35 l	p Fe Cr	10	10	Not seen separately.
5284·28	25 l	...	10	2– 6	Fraunhofer line assigned to Ti by Rowland, but not by Hasselberg.
5316·79	45 l	p Fe	100	2–20	"1474 K."
5324·37	15 s	Fe	...	...	Not in Young's list.
5325·46	20 l	...	2	2	Fraunhofer line assigned to Co by Rowland.
5328·24	25 s	Fe	3	2	
5328·70 5328·75	15 s	Fe Fe	3	2	Not seen separately.
5340·12	10 s	Fe	...	...	Not in Young's list.
5341·21	10 s	Fe	2	1	
5363·06	30 l	...	20	5–10	
5365·07	10 s	Fe	1	1	
5367·67	10 s	Fe	1	1	
5371·66 5371·73	20 s	Cr Fe	10	3	Not seen separately.
5381·22	10 l	p Ti	3	2	Dark line attributed to Fe by Rowland
5383·58	10 s	Fe	...	...	Not in Young's list
5393·38	15 s	Fe	2	1	
5397·34	25 s	Fe	4	2	
5404·36	10 s	Fe	5	3	
5405·99	25 s	Fe	2	1	
5425·46	30 l	...	25	6	
5429·91	30 s	Fe	8	3	
5434·74	20 s	Fe	2	2	
5447·13	25 s	Fe	0	4	
5455·83	20 s	Fe	10	4	

1905MNRAS..65..513F

Wave-length.	Intensity and Character.	Probable Origin.	Young.		Remarks.
			Frequency.	Brightness.	
5477·12	20 s	Ni	1	1	
5527·03	20 l	Sc	? 40	? 5	Probably Young's line 5525·9 (A°), which is wrongly corrected to 5528·64 (R) and attributed to Mg.
5535·06	35 l	...	50	12	Perhaps slightly less refrangible than 5535·0, but certainly not 5535·7 Ba; dark line attributed to Fe by Rowland.
					Definition poor from here, and eruption perhaps less active.
5875·87	95 l	He	100	90	D_3; very long and bright, and expanded in places.
5890·19	40 s-l	Na	25	2–10	D_2 A little longer than most of "short" lines, with brighter "hump."
5896·16	40 s-l	Na	25	2–10	D_1
5991·60	15 l	...	15	2– 5	
6141·94	20 s-l	Fe, Ba	15	3– 5	Moderate length, with brighter "hump."
6238·60	15 l	...	10	2	
6247·77	20 l	...	10	4	
6347·3	25 l	...	10	3	
6369·7	10 l	...	5	3	
6371·6	15 l	...	5	3	Dark line assigned to Fe by Rowland.
6432·9	25 l	...	10	2–10	
6456·60	20 l	p Fe	15	3–10	Author's identification.
6497·13	20 s-l	Ba, Fe	18	3–15	Moderate length, with hump.
6516·3	30 l	...	15	3–10	Perhaps a little more refrangible than dark line.
6563·05	100 l	H	100	100	C.
6678·3	35 l	He	25	10–50	
7065·5	35 l	He	100	5–20	

It will be seen that the above list is in close agreement with that of Young, so far as the two are comparable. In the region between b_4 and 5363, included in Young's revision, there is, in fact, only one line of intensity greater than 2 which does not appear in the table—namely, 5226·7 (5); and this may well have been missed in consequence of poor seeing when that region was under observation. In the red end Young's line 6191·8 is the

1905MNRAS..65..513F

only line of greater intensity than 3 which I did not record. Three short iron lines of low intensity which I observed, probably in moments of good seeing, are not given by Young, but two of them occur in Lockyer's table of eclipse lines. The long line of scandium at 5527·03 is probably identical with a line observed by Young, which has been assumed to be the adjacent magnesium line 5528·64 when correcting from the scale of Ångström to that of Rowland. I have seen it on other occasions in metallic prominences, and am quite certain of its position. Notwithstanding the generally higher intensities which I have assigned to the shorter lines as compared with those given by Young, it would thus appear that the spectrum of the disturbed chromosphere is remarkably constant.

A comparison with the flash spectrum, as recorded by prismatic cameras, indicates that the long arcs of the eclipse spectra are represented by long lines in the foregoing table, suggesting that over a spot there is a general elevation of the chromospheric layers with little intermingling.

So far as it is possible to make a comparison of the bright chromospheric lines of February 11 with the affected dark lines previously noted in the spot, it appears that the high level lines were not among those intensified in the spot, while the common lines were chiefly those of iron, chromium, and calcium, which appear as strong Fraunhofer lines.

Addendum, 1905 *March* 13.

Brilliant prominences were again observed in the neighbourhood of the decaying spot when it was near the western limb on the morning of March 10. Many bright lines were seen, and the twenty-one identified were identical with long lines observed on February 11, and had the same relative intensities.

The Seasonal Variation in Magnetic Disturbance, with other Remarks. By William Ellis, F.R.S.

In my paper, *Monthly Notices*, 1899 December, I showed, from the records of the Royal Observatory for the fifty years 1848–97, that there existed greater frequency of magnetic disturbance at Greenwich at or near the equinoxes, and a lesser frequency at or near the solstices; and in again referring to this question, *Monthly Notices*, 1901 June, I said that "the spring maximum appears, on the whole, to fall somewhat before the equinox, and the autumn maximum somewhat after the equinox." I propose now, from the material contained in the first-mentioned paper, to endeavour to locate these points more precisely. At p. 153 of that paper the number of days of moderate, active, and great